

Building a Bridge to the Corn Ethanol Industry

Comparison of Contract Results

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Bridge Goals

- Provide industry opportunity to explore business potential
- Take advantage of existing corn ethanol industry infrastructure
- Obtain feedback to guide research for commercialization

Bridge Objectives

- Develop a co-location scenario
- Identify feedstock costs and availability
- Determine capital and operating costs
- Produce a Pro forma and perform sensitivity analyses

Participants

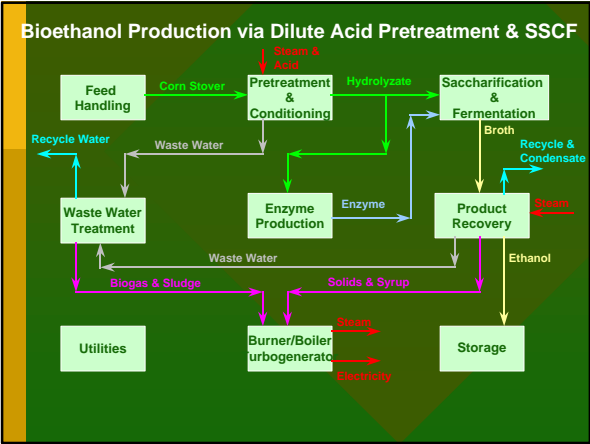
- Merrick/High Plains Ethanol/PureVision Technologies
- Vogelbusch/Chief Ethanol/KAPPA
- LORRE/Williams Energy Services/USDA NCAUR
- NYSTEC/Robbins Corn/Raytheon
- UNDERWAY:
- Weatherly/High Plains Ethanol/SWAN
- Delta T/Chippewa

2 Basic Process Designs

- 3 contractors chose:
 - corn stover feed
 - dilute acid pretreatment
 - enzymatic hydrolysis
 - recombinant *Z. mobilis*
- 1 contractor chose:
 - corn fiber feed
 - hot water pretreatment
 - enzymatic hydrolysis
 - yeast

Site choice and plant size

- 2 of the 3 corn stover plants are co-located with a corn dry mill facility in Nebraska, both rated at around 25MM gallons per year
- The other is a stand-alone facility in New York state, rated at 60MM gallons per year



NREL provided:

- Design Report with Process Flow Diagrams
- Capital and operating cost database
- Equipment specifications
- Technical process support

Most Significant Results

- Only corn fiber (Purdue) process resulted in production costs below the anticipated ethanol selling price
- All corn stover processes had low or negative returns over the plant life
- Use of existing plant infrastructure was nonexistent due to recombinant organism

Corn Stover Processes

	Merrick	NYSTEC	Vogelbusch	NREL
Plant Type	co-located	stand alone	co-located	stand alone
Plant Feed rate (dry ton/day)	992.07	2400	936.955	2205
Annual Production (MM gal/yr)	25.7	60	23.5	49
Yield (gal/dry ton)	74.1	71.4	72.2	63
On-stream hours	8400	8400	8400	8406
Year for cost basis	1999	1997/1999	1999	1997

Feedstock Costs

	Merrick	NYSTEC	Vogelbusch	NREL
Feedstock	corn stover	corn stover	corn stover	corn stover
Cost (\$/dry ton)	\$35	\$35	\$43 to \$46	\$25
Cost (\$/gal EtOH)	\$0.47	\$0.49	\$0.61	\$0.39
Cost basis	NE growers/Iron Horse	NY growers	NE growers/Chief	
Type of System	established		current	established
Feed handling capital (\$MM)	6.1	5.7	10.3	3.7

Contractors' Enzyme Costs

	LORRE	Merrick	NYSTEC	Vogelbusch
Enzyme Source	Purchased	Produced on-site	Produced on-site	Assumed Purchased
Cost Reference	Cellulase Supplier	PureVision	NREL	NREL
Enzyme Cost (\$/gal Ethanol)	\$0.0387	\$0.20	\$0.30	\$0.30

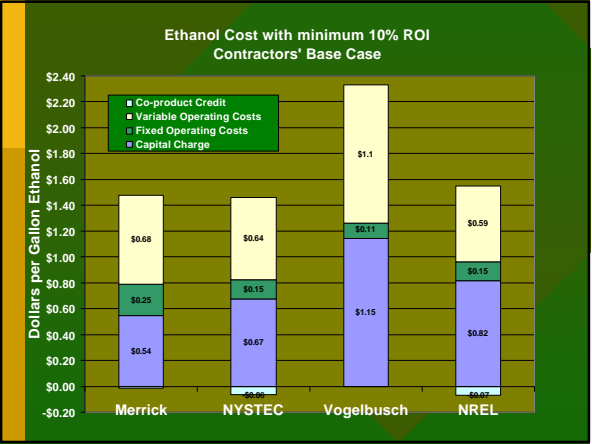
Utilities and Co-products				
	Merrick	NYSTEC	Vogelbusch	NREL
Steam production	gas	biomass	biomass	biomass
Electricity	\$0.035/Kwh	generated	generated	generated
Lignin fate	sold	burned	burned	burned
Co-product	Methane	electricity	none	electricity
Co-product value	\$2.50/MMBtu	\$0.035/Kwh	\$0.00	\$0.04/Kwh
Co-product credit (\$MM/yr)	\$0.33	\$3.80	\$0.00	3.3

Financing/Costing				
	Merrick	NYSTEC	Vogelbusch	NREL
Plant Life (yr)	20	20	12	20
Depreciation Method	SL	SL	SL	DB
Depreciation Term (yr)	15	15	15	20
Financing				
Equity	0.25	0.3	0.3	1
Interest rate	0.07	0.11	0.1	7.5
Loan term	15	15	15	10
Cost escalation	3%		2% for costs	require 10% ROI
Other	10% grants		no price escalation	
Ethanol selling price (\$/gal)	\$1.10	\$1.15	\$1.15	10% ROI

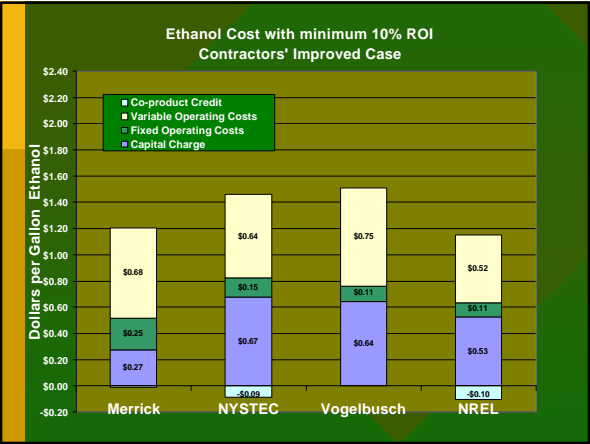
Capital and Operating Costs				
	Merrick	NYSTEC	Vogelbusch	NREL
Capital (\$MM)	\$79.4	\$230.0	\$153.0	\$227.2
Capital (\$/annual gal)	\$3.09	\$3.83	\$6.51	\$4.64
Annual Depreciation (\$MM/yr)	\$5.3	\$15.33	\$10.20	\$11.36
Capital Charge (\$MM/yr)	\$14.0	\$40.48	\$26.93	\$39.99
Fixed operating costs (\$MM/yr)	\$6.3	\$8.9	\$2.7	\$7.3
Variable operating costs (\$MM/yr)	\$17.6	\$38.3	\$25.2	\$28.7

- ### How the processes were compared
- Each contractor used different pro formas (economic assessment tool)
 - NREL engineers used a common capital charge factor to compare the different contractor processes
 - Normalizes owner equity and other loan factors, and return on investment to 10%

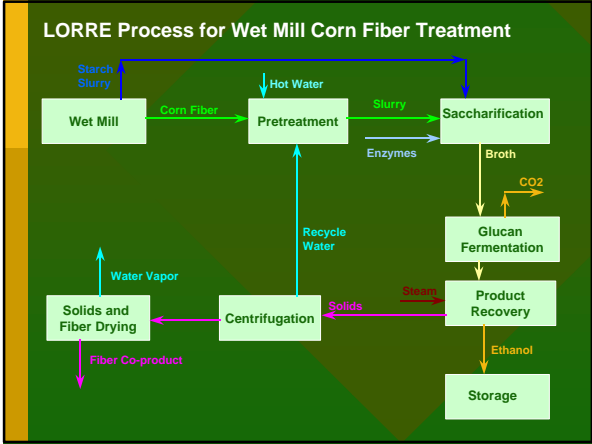
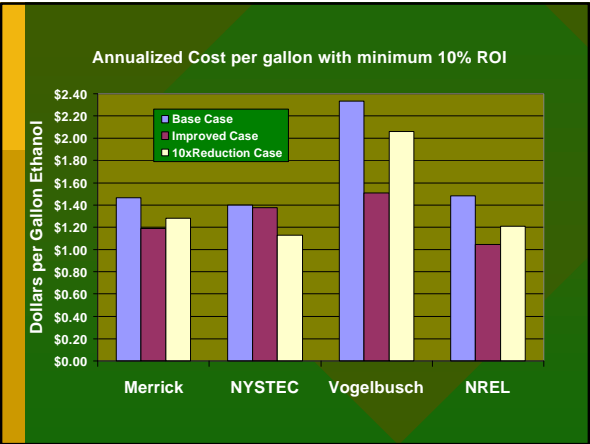
Contractors' Base Case Process				
	Merrick	NYSTEC	Vogelbusch	NREL
Contractors' Pro forma results	1% annual avg. ROI	\$0.604MM cumulative profit	\$22MM avg annual loss (-14.5% annual ROI)	
10% ROI				
Annual Production Cost (\$/gal)	\$1.46	\$1.40	\$2.33	\$1.48



Contractors' Improved Process				
	Merrick	NYSTEC	Vogelbusch	NREL
Improvements		Increase value of electricity credit by 35%	Combined 20% yield increase, \$10/ton feed cost reduction, 0.20/gal enzyme cost reduction, 42% capital cost reduction, loan rate reduction	
Contractors' Pro forma results	21% ROR	18.262MM cumulative profit	\$0.126MM avg annual profit (0.17% ROR)	
10% ROI				
Annual Production Cost (\$/gal)	\$1.19	\$1.38	\$1.51	\$1.05



Enzyme 10x Cost Reduction Scenario (NREL)				
	Merrick	NYSTEC	Vogelbusch	NREL
10% ROI				
Annual Production Cost (\$/gal)	\$1.28	\$1.13	\$2.06	\$1.21



Corn Fiber Process Feed	
Plant Type	co-located with wet mill
Location	not provided
Process	Hot water/Enzymatic Hydrolysis
Plant Feed rate (dry ton/day)	495
Annual Production (MM gal/yr)	8.2
Yield (gal/dry ton)	47.5
On-stream hours	8400
Year for cost basis	1999
Feedstock	corn fiber
Cost (\$/dry ton)	\$65.00
Reported Cost (\$/gal EtOH)	\$0.55
Calculated Cost (\$/gal EtOH)	\$1.37
Cost basis	Carbohydrate component only
Feed handling area installed capital (\$MM)	\$0.05

Corn Fiber Process Costs	
	LORRE
Steam production	assumed \$1.8-5 per MMBtu
Electricity	purchased - not provided
Lignin fate	none
Plant Life (yr)	10+
Depreciation Method	SL
Depreciation Term (yr)	10
Financing	not provided
Ethanol selling price	\$1.00
Co-product credit (\$MM/yr)	fiber at \$65/dry ton
Costs	
Capital (\$MM)	\$9.0
Capital (\$/annual gal)	\$1.10
Annual Depreciation (\$MM/yr)	\$0.90
Capital Charge (\$MM/yr)	\$1.62
Fixed operating costs (\$MM/yr)	not provided
Variable operating costs (\$MM/yr)	not provided

Corn Fiber Process Cases	
	LORRE
Contractor's Base Case	
Reported value	.73 to .82
Contractor's Improved Case	
Improvements	Lower fiber value/cost to \$40/ton
Reported value	0.58 to .67
10x reduction in cellulase costs	
Cellulase enzyme Source	Purchased for \$0.0387/gal
Reported value	.73 to .82

Co-location Benefits...	Wash-outs...
<ul style="list-style-type: none"> Land rail, load-out facility lab/operator experience permitting in place 	<ul style="list-style-type: none"> Infrastructure sharing low capital cost ready feedstock enzyme prices available

Biggest Cost Impacts to Process
<ul style="list-style-type: none"> Feed cost Capital cost Yields Debt/Equity ratios Ethanol selling price

Subcontract Value
<ul style="list-style-type: none"> Enzymatic process is not yet cost effective Survey of feed prices and availability Check of NREL capital costs Feed handling design Some enzyme costing/design Wastewater treatment design

Contractors' Recommendations for Research
<ul style="list-style-type: none"> Get GMO acceptance Reduce capital costs Find market for lignin Determine <i>Z. mobilis</i> hardiness for production Do pilot scale work with stover Reduce feed costs

Were the Goals of the Bridge Achieved?				
	LORRE	Merrick	NYSTEC	Vogelbusch
Goals:				
Provide opportunity to industry	Yes	No	No	No
Use plant infrastructure	Yes	No	No	No
Obtain feedback	Yes	Yes	Yes	Yes
Objectives:				
Identify feedstock costs	Yes	Yes	Yes	Yes
Identify feedstock availability	Yes	Yes	Yes	Yes
Determine equipment needs	Yes	Feed/WWT	Feed	Feed/Distillation
Determine costs	Yes	Yes	No	Yes
Pro forma/sensitivities	Yes	Yes	Yes	Yes

- ### Contractors' Implementation Plans
- Purdue is planning a 1/9th scale pilot plant to demonstrate hot water on fiber
 - NYSTEC plans to pursue business plant for a corn ethanol plant
 - Merrick/High Plains and Vogelbusch/Chief have no plans